Modeling and Control Methods for Supporting Scapulohumeral Rhythm with a Robotic Exoskeleton

Completed Technology Project (2016 - 2018)

Project Introduction

The shoulder is a highly mobile joint complex that depends on the movements of three component articulations. Biomechanics research has shown an inherent coordination pattern among these joints during various movements, which has been termed scapulohumeral rhythm (SHR). This motion is considered important for proper shoulder function, and alterations in this coordination have been correlated with an increased risk for impingement and other musculoskeletal injuries. A tiger team review found that contemporary space suit (Extravehicular Mobility Unit, or EMU) designs limited the shoulder motion of crewmembers and contributed to shoulder injuries experienced during training. While current NASA efforts are being made to address this issues in upcoming suit designs, other restrictions on suit geometry or operating conditions are difficult to address with these methods. These include additional resistance from suit pressurization and fatigue during extended extravehicular activity (EVA). One possible solution is to use robotic devices, such as powered exoskeletons, in tandem with these suit changes. Providing direct support for proper shoulder motion in the presence of configuration- and time-dependent disruptions could reduce the risk of shoulder injury and improve EVA performance. The goal of this research is to explore robotic exoskeletons as a means to correct and support proper shoulder complex motion in the presence of environmental and physiological disturbances. This will begin with the development a novel kinematic model of the shoulder complex that can be used to estimate the configuration of the scapula. The model will use a reduced set of measurements relative to traditional motion capture methods, which are infeasible in highly occlusive environments. This will be followed by the design and evaluation of a mechanism for directly mobilizing the scapula during various tasks. This system will be compared with an existing upper body exoskeleton in terms of range of motion, joint loads, and other dynamic properties. This work will conclude with the formulation of robot control strategies for supporting and modifying scapular motion. These algorithms will be responsive to pressurized suit resistance, variable loading from tool use, and crewmember fatigue. This research will use Harmony, an existing upper body exoskeleton in the ReNeu Robotics Lab, as a platform for testing these concepts. The project will also utilize NASA resources on astronaut anthropometry and EMU characteristics to ensure applicability to mission objectives. The outcomes of this work will support Technical Areas 7.3 (Human Mobility Systems) and 6.2 (Extravehicular Activity Systems) by furthering knowledge of shoulder biomechanics and exploring new methods to reduce the incidence of EVA injury. In the future, these findings can support the development of assistive exoskeletons for use in both spaceflight and planetary missions. The shoulder is a highly mobile joint complex that depends on the movements of three component articulations. Biomechanics research has shown an inherent coordination pattern among these joints during various movements, which has been termed scapulohumeral rhythm (SHR). This motion is considered important for proper shoulder function, and alterations in this coordination have been correlated with an increased risk for impingement

SPACE TECHNOLOGY MISSION DIRECTORATE

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Anticipated Benefits

This research is important to several areas that are related to EVA mobility and astronaut health. First, quantifying the suit resistance, joint loads, and associated shoulder motion are vital to future redesigns of the EMU in order to reduce crew injury rates and increase the suit's mobility. This work will be important for astronaut medicine, as the information on muscle use and joint loads during EVA training can improve the prevention, diagnosis, and treatment potential shoulder problems. In addition, if future spacesuits incorporate technologies that allow for strength augmentation (such as those found in existing upper body exoskeletons), this information on joint forces and muscle use is necessary to ensure that these devices do not injure crew

Organizational Responsibility

Responsible Mission Directorate:

Space Technology Mission Directorate (STMD)

Lead Organization:

The University of Texas at Austin

Responsible Program:

Space Technology Research Grants

Project Management

Program Director:

Claudia M Meyer

Program Manager:

Hung D Nguyen

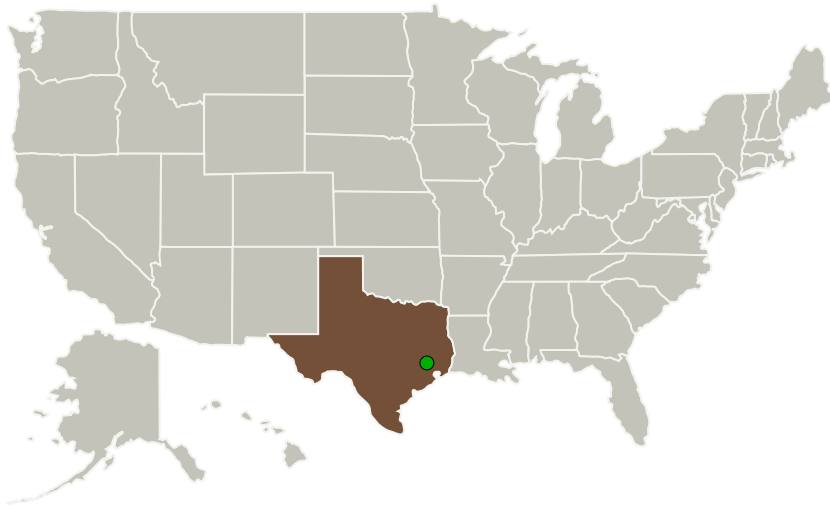**Principal Investigator:**

Ashish D Deshpande

Co-Investigator:

Evan M Ogden

members.

Primary U.S. Work Locations and Key Partners

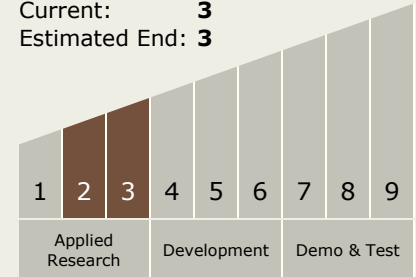| Organizations Performing Work	Role	Type	Location
The University of Texas at Austin	Lead Organization	Academia	Austin, Texas
🟢 Johnson Space Center(JSC)	Supporting Organization	NASA Center	Houston, Texas

Primary U.S. Work Locations
Texas

Project Website:

https://www.nasa.gov/strg#.VQb6T0jJzyE

Technology Maturity (TRL)

Start: **2**
Current: **3**
Estimated End: **3**

1	2	3	4	5	6	7	8	9
Applied Research			Development			Demo & Test		

Technology Areas

Primary:

- TX06 Human Health, Life Support, and Habitation Systems
  └ TX06.3 Human Health and Performance
    └ TX06.3.2 Prevention and Countermeasures

Target Destinations

Earth, The Moon, Mars